EPT Field Report

Interim Field Investigations in Uzbekistan: Nukus and Urgench Water Treatment Plants

September 1994

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Acronyms

AED	Academy for Educational Development
CAR	Central Asian Republics
EAP	Environmental Action Plan
EPT	Environmental Policy and Technology
gpd	gallons per day
gpd/sf	gallons per day per square foot
gpm/sf	gallons per minute per square foot
GOST	State Standard of the Soviet Union
GOU	Government of Uzbekistan
mg/L	milligrams per liter
MOU	Memorandum of Understanding
NET	NIS Exchanges and Training
NIS	Newly Independent States
NTU	nephelometric turbidity units
O&M	Operation and Maintenance
TDS	Total Dissolved Solids
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
USG	United States Government
WHO	World Health Organization
WTP	Water Treatment Plant

Executive Summary

The Nukus and Urgench Water Treatment Plants (WTP) are modern, well designed, conventional surface water treatment plants constructed in 1985 and designed to produce 200,000 m^3/day of potable water. State of repair of the plants is generally good. However, at both plants, the chlorination systems and laboratories need upgrading with new equipment.

The main problem with the plants is that they are not producing potable water by international standards, i.e., the World Health Organization (WHO) and the U.S. Environmental Protection Agency (USEPA). This is due to a combination of two factors. The first factor is antiquated, local standards known by the acronym, GOST, and handed down from the Soviet era. These standards allow highly turbid – nephelometric turbidity units (NTU) > 10 – and poorly disinfected finished water (no free chlorine and essentially no combined chlorine). The second factor is deficient operation of some unit processes, including primary clarifiers and sand filters.

The main concern is that microbiological contaminants such as bacteria and protozoa are believed to be routinely present in the finished water. These contaminants are likely causing acute (infectious) health problems to populations served by these plants. While the plants are not meeting international drinking water standards related to these contaminants, both plants have the unit processes and operations; that is, clarification, filtration, and chlorination, needed to achieve these standards. Relating to microbiological contaminants, the only facility improvements needed are new chlorination (disinfection) equipment and upgraded laboratory equipment. Improved operational methods, as noted in this report, are also needed to optimize clarifier and filter performance.

Other contaminants – such as inorganics (metals, etc.), synthetic organics (pesticides, etc.), volatile organics (solvents, etc.), and radionuclides – if present in the raw water are probably not being removed by the treatment plants. These anthropogenic (man-made) chemicals could cause chronic health problems. At elevated levels they are toxic to human health.

To assess the potential impacts on the people receiving this water, the concentration of these contaminants in the raw water needs to be established. Once these concentrations are established, risk assessment studies can be done to establish the threat to public health, and whether advanced treatment systems are needed. Installation of new and upgraded treatment is not advised until risk assessment and treatment feasibility studies are completed.

Finally, highly turbid and minimally disinfected water has apparently been pumped into the transmission main(s) and distribution systems for almost 10 years. As a result, the pipelines are probably contaminated with bacterial slime growths. Study is needed to determine chlorine residuals downstream from the plants and to assess alternatives for downstream treatment of water. Alternatives include additional chlorination systems and/or small treatment plants located in the cities. The study could also define other needed improvements such as booster pumps and new pipe.

Section 1
Introduction

1.1 Background

The Memorandum of Understanding (MOU) between the Government of Uzbekistan (GOU) and the United States Government (USG), administered through the U.S. Agency for International Development (USAID), was executed April 20, 1994. This MOU established certain understandings between the two countries, with U.S. assistance targeted at providing potable water and other environmental improvements to the Amu Darya (Amu River) delta area of Uzbekistan. The project area includes the Republic of Karakalpakstan (part of Uzbekistan), with its main city of Nukus, and the Khorezm Oblast of Uzbekistan, with its main city of Urgench. Figure 1 (page 1-2) provides a location map of the project area.

Specific tasks identified in the MOU included physical and operational improvements to the Nukus and Urgench WTPs. However, little actual site information was available at the time the MOU was written. To provide a better basis on which to develop any design documents and to better understand how the plants are operated, a site inspection of the plants was authorized by USAID as part of Delivery Order 04 executed on May 3, 1994. The inspection was done by a specialist in water plant design/operations. This report summarizes the observation, conclusions, and recommendations of this site visit.

Other tasks under Delivery Order 04 included site inspection of the facilities in Kazakhstan, a preliminary assessment of the public health needs in Kazakhstan and Uzbekistan, and a preliminary Environmental Action Plan (EAP) for the region. These tasks are not included in this report.

1.2 Project Team

Field investigations were conducted by Mr. William Gierer, EPT operations specialist, who has 20 years of experience in the optimization of water treatment plant operations. The field work was completed during the period June 13-30, 1994. Of this total, 8 days were spent at the Nukus plant and 1 day at the Urgench plant. Mr. Dilya Zuparkhodzhayeva, USAID representative in Uzbekistan, and Mr. Paul Dreyer, EPT regional director for Central Asian Republics (CAR), also participated in the plant visits, June 13-18. U.S.-based EPT team members working on this project include Mr. Henry Sheldon, project manager, Rita Klees, Ph.D., director of technology, and Syed Mahmood, CAR program coordinator.

1.3 Scope of Work

The scope of work for this project was to visit both the Nukus and Urgench water treatment plants to evaluate the plant facilities and operations. Specific tasks were as follows:

- Interview the plant operators to understand how the plants are operated.

- Collect design data and detailed sketches of the facilities.

- Prepare an inventory of major equipment and actual conditions.

- Identify low-cost rapidly implementable activities to improve plant performance.

- Prepare an inventory of laboratory equipment and reagents, and identify rapidly implementable laboratory improvements.

The scope of work included only investigations at the two treatment plants. Off-site investigations, e.g., of the distribution and delivery systems, were not included in the scope of work.

Section 2
Water Quality

2.1 Raw Water Quality

The Nukus and Urgench WTPs obtain their raw water from the Tuyamuyum Reservoir on the Amu Darya, as shown in Figure 1. River water quality varies considerably throughout the year with best quality occurring in the spring and early summer months due to dilution from snow melt. Deteriorated water quality is most common in the dry months of September and October. The primary cause of deteriorated water quality is believed to be agricultural drainage upstream of the reservoir. The influent water at the time of the inspection smelled of agricultural chemicals.

No historic raw water quality data was available at the time of the site visit. However, several samples of influent water (at the junction box) were collected and a few parameters analyzed at the site. Average values for the parameters evaluated are summarized in Table 2-1.

Table 2-1
Raw Water Quality

Parameter	Unit	Units
Temperature	Degree C	29
Turbidity	NTU	20 to 70
pH	unit	8.5 to 8.7
Hardness	mg/L	250
Total Alkalinity	mg/L	90
Nitrates	mg/L	0.8
TDS	mg/L	600

2.2 Water Quality Standards

Both treatment plants are presently operating under water quality standards promulgated in 1982 by GOST 2874-82. A comparison of these standards, with current (1994) WHO guidelines and USEPA standards, is included in Appendix A. While the GOST standards for some water quality parameters are essentially the same (Nitrates, Arsenic, Iron, Copper, Zinc, Fluorides & Odor) as the WHO guidelines and USEPA standards, other standards (Aluminum, Magnesium, Nitrates, Lead, Manganese, Sulfates, Chlorides, Turbidity and microbiological) are less strict.

Two of these standards are of major concern for acute impacts on public health. These are turbidity and microorganisms. The USEPA standard for turbidity is 0.5 NTU and the

WHO
guideline is 1 NTU. The GOST standard is presently 1.5 equivalent mg/L of turbidity, which by comparative testing accomplished during the site visit, is approximately 20 NTU. The resultant water produced by the plants, although meeting GOST standards is, by USEPA standards or WHO guidelines, highly turbid, aesthetically unattractive and microbiologically unsafe.

There is a direct relationship between turbidity and microbiological contamination. Microbiological organisms, such as bacteria and protozoa, can attach themselves to suspended solids and thus be protected from disinfection (chlorine) agents. Although there is a disinfection requirement (0.3 to 0.5 mg/l of free chlorine with a detention time of 30 minutes) in the GOST standards, this requirement was not being met at the plants at the time of the field investigations. The GOST standards appear to allow bacteria and giardia to be present in numbers (100/m^3 and 3/L, respectively) which are totally unacceptable by USEPA standards and WHO guidelines. Thus while the plants produce turbid and minimally disinfected water that meets GOST standards, this finished water is very likely contributing to the acute public health problems in the delta.

2.3 Finished Water Quality

Finished water quality data collected and tested at the Nukus WTP is summarized in Table 2-2. Samples were collected from the reservoir or at the distribution pump station. No existing data or records from the Nukus WTP were made available. Data provided for the Urgench WTP is also summarized in Table 2-2. No independent samples were allowed to be collected at the Urgench plant.

At the Nukus WTP, although chlorine was being fed to the horizontal clarifiers and to the facility clearwells, at no time could a free chlorine residual be obtained. When measuring for a total chlorine residual a slight color change could be observed but could not be measured on the spectrophotometer. No data was made available on the chlorine residual at the Urgench WTP.

Table 2-2
Finished Water Quality

Parameter	Unit	Nukus WTP	Urgench WTP
Turbidity	NTU	14	10
Hardness	mg/L	260	NR
pH	unit	8.5	7.0
Alkalinity	mg/L	85	NR
Nitrates	mg/L	0.45	NR
TDS	mg/L	580	NR

NR = not reported

Section 3
Design Features of Water Treatment Plants

The Nukus and Urgench WTPs are identical in design and capacity. Both are conventional surface water plants consisting of coagulation, sedimentation, filtration, and disinfection. The capacity of each plant is 200,000 m^3/day (52.8 mgd); both were constructed in 1985. At the time of the site visits in June 1994, both plants were producing water at their design capacities. Production rate is based on maintaining dictated pressure in their respective distribution pipelines.

Figure 2 (page 3-2) is a schematic process diagram of the plants. Nukus and Urgench WTP design criteria are summarized in Appendix B.

3.1 Nukus WTP

The Nukus WTP is located approximately 280 km (174 miles) up river from Nukus as shown in Figure 1. It pumps treated water to the city via a buried conduit. The facility contains two identical treatment trains.

The plant is operated on a completely manual basis and only the raw water influent to the plant is measured. The laboratory equipment is old but usable and is used to determine plant water quality twice a day. (In the United States, these analyses are required every 2 hours.) There is concern on the ability to produce laboratory results that are reliable and repeatable.

3.2 Pretreatment

Water from the reservoir (at the power plant) is pumped approximately 1,000 meters via an intake pump station through an open earthen loop canal to the plant's influent pump station. The intake pump station is operated by the power authority (not the water plant staff). It pumps continuously through the canal, diverting water not withdrawn by the influent pump station back to the river via a loop section of the canal. Raw water in the canal passes through four manually cleaned trash racks. The water plant staff maintains these trash racks.

The influent pump station consists of a concrete building housing the pumps and motors atop a wet well located adjacent to the canal. Immediately preceding the pump station in the main canal is another set of trash racks. After the water passes through this set of racks, it enters pipes that lead to the individual wet wells for each of the four constant speed pumps. Located in each of the wet wells ahead of the pumps are traveling screens to provide for finer screening.

The influent pump station contains four constant speed pumps each rated at 120,000 m^3/day. Operating pressure is 3 atmospheres. Only two pumps are needed to pump the design flow. The station is split into two sections with two pumps in each section.

Screened (coarse and fine) water is pumped by the influent pump station 1.6 km (1.0 mile) via a buried pipe to a junction box at the water treatment plant. This junction box diverts flow to clarifiers for primary treatment, i.e., sedimentation.

3.3 Primary Clarification

Primary treatment consists of coagulant aided quiescent settling in four 50 meter diameter circular (radial), clarifiers, two per train. Each of the clarifiers is rated at 60,000 m^3/day.

The junction box ahead of the clarifiers contains four "hydraulic jumps" which are used to mix the coagulant chemical, aluminum sulfate (alum). A coagulant aid, a type of polyelectrolyte (polymer acrilamide) can also be fed at the junction box. After the junction box, the flow is split between the two trains.

The primary clarifiers are operated to provide 1.5 hours of detention time to allow the flocculated particles (floc) to settle. The accumulated particles (sludge) are removed in a conventional manner, i.e., by means of four rotating, mechanical scraper arms, controlled from the center of the clarifier. The scraper arms direct the sludge to the center of the clarifier's floor where six openings direct the sludge to a pipe leading to the sludge pumping station wet well.

Treated (clarified) water is discharged as overflow from the clarifier which enters a peripheral launder through 5-cm (2-inch) holes, approximately 0.3 m (1 foot) below the water surface and 1 m (3.3 feet) apart. The combined water from the two clarifiers (per train) is piped via the launder flumes to a common channel linking the two trains. This channel diverts the primary treated water to mixing basins to begin secondary treatment.

3.4 Secondary Clarification

Secondary treatment consists of additional quiescent settling accomplished in rectangular (horizontal) clarifiers. There are nine clarifiers per train or 18 total. Prior to entering these clarifiers, the primary treated water is directed to one of four secondary mixing basins.

These basins are "up flow" designs with fixed mixing plates that provide for further coagulant and coagulant-aid addition, depending on the water quality from the primary clarifiers. When chemical addition is not required, the mixing basins can be by-passed with flow directed to the secondary clarifiers via a common inlet channel. Chlorine is added in this inlet channel which serves as the primary point of disinfection in the plant.

Each of the secondary clarifiers are 6 meters wide by 90 meters long. Water depth is 4.5

meters. Rated capacity of each clarifier – assuming one clarifier per train out of service – is 12,500 m^3/day. This equates to about 560 gallons per day per square foot of surface area (gpd/sf) which is consistent with U.S. design standards for rectangular clarifiers. The first 20 meters of length of each clarifier is a flocculation section and the last 70 meters is a settling section. Clarifiers are operated to provide 3 hours of detention time.

During the winter months, when raw water turbidity is low, the raw water can be diverted at the influent junction box to bypass the primary clarifiers and directly routed to the secondary clarifiers via the inlet channel.

Solids (sludge) that settle to the bottom of the floor of the secondary clarifiers are allowed to accumulate and are normally removed annually by taking the clarifier out of service. With the clarifier drained, these solids are washed to the sludge pumping station using primary clarifier effluent under pressure. Depending on the amount of sludge accumulation, this flushing can occur semi-annually.

Treated (clarified) water is discharged as overflow through effluent troughs with holes in the side walls. The effluent from the nine clarifiers discharges into a common channel which links both of the trains.

3.5 Filtration

Water in the common effluent channel from the secondary clarifiers enters the inlets to one of nine, rapid sand, gravity filters. Rated capacity of each filter is 12,500 m^3/day based on meeting rated plant flow (200,000 m^3/day) with only eight filters operating per train. This allows one filter per train to be out of service for backwashing.

Each filter is 9 meters long, 6 meters wide and has 2 meters of sand. Design hydraulic loading rate is 0.16 m^3/m^2/min. This equates to about 3.9 gpm/sf, which should be a sufficiently low enough loading rate to achieve good particulate removal in a mono media filter, assuming the filters and preceding unit processes are optimumly operated.

However, because of the following conditions, the filters are probably not achieving good particulate removal:

- The preceding chemically aided clarification processes are not operated optimally in that coagulant addition in the primary clarifiers is often deleted.
- Filter backwash timing is not based on optimal conditions but on maximum head loss or when the rate of filtration has been reduced to a minimum.
- There are no backwash-aid devices such as surface washing or air scrubbers, therefore the backwash process probably leaves a "dirty" filter.
- After completing a backwash cycle, water is often reloaded onto dry sand media.

The sand media should always be covered with water so as to prevent channelization of the media from influent loading.

- When some of the filters are off-line the remaining on-line filters are being hydraulically overloaded. With five of the eight filters out of service in train No. 1, as was observed during the site visit, the equivalent loading on the remaining three on-line filters is in excess of 10 gpm/sf – an excessive loading rate for a mono media filter. Samples collected of filtered water from on-line filters with five filters out of service indicated that turbidity in the filtered water ranged from 4 to 13 NTU. These filters should achieve much better turbidity removal if better operating conditions are im plemented.

The backwash wastewater leaving the filters enters a drain piping system which transports the water to a wastewater lagoon where the sludge is allowed to settle and the effluent water discharged to the Amu Darya.

Filtered effluent flows into a common header which links the two trains. The water in the common header is chlorinated (post disinfection) prior to the water entering the distribution clearwells and backwash/service water reservoirs.

3.6 Clearwells

There are three distribution clearwells and three smaller backwash/service water reservoirs. The three distribution clearwells supply water to the distribution pumping station while the backwash/service water reservoirs supply the backwash/service water pumping station.

3.7 Distribution Pump Station

The distribution pump station consists of six constant speed pumps. Attached to each of the pump's discharge piping is a pressure booster pump. The booster pumps are needed to assist in delivering water with acceptable pressures to the city of Nukus.

3.8 Chemical Feed Systems

3.8.1 Alum System

The alum feed system consists of six, alum mixing/solution tanks where dry "rock" alum is broken up and added to the water. With the alum added to the solution tanks, air blowers and piping in the tanks are used to ensure a proper alum and water mixture. Once the alum solution is mixed, the solution is transferred to either three liquid solution storage tanks or to the two alum feed tanks. The feed tanks serve as the supply to three dual-headed positive displacement, variable speed and stroke feed pumps.

3.8.2 Coagulant Aid System

The polymer acrilamid feed system consists of two polymer mixing/solution tanks where "bagged" liquid polymer is added to water. With the polymer and water properly mixed using mechanical mixers, the polymer is transferred to one of two polymer storage tanks.

The storage tanks serve as the supply to three-dual headed positive displacement, variable speed feed pumps. One feed pump is used in normal operation with the other two serving as standby units. During the field investigation no polymer was being added.

3.8.3 Chlorine System

The chlorine supply system consists of one, 800 kg (1,765 lb) tank with provisions for two additional 50 kg (110 lb) cylinders. The chlorine is withdrawn in its gaseous form under pressure.

Chlorine gas is transferred (piped) to the chlorine feed room. In the chlorine room, one of several (approximately eight) vacuum-operated chlorinators regulate the amount of chlorine that is fed to the finished water. Five of the chlorinators are dedicated to primary disinfection while the other three are dedicated to final (clearwell) disinfection. Only four of the eight chlorinators were functional. All the equipment is antiquated and should be replaced.

3.9 Laboratory

The Nukus WTP laboratory contained only rudimentary equipment such as pH and turbidity meters, both of which read in milliamps with actual values having to be converted from tables. Most of the chemical analyses were accomplished by wet chemistry titrations. These included hardness, alkalinity, and chlorine. The method used to measure chlorine utilized methyl orange, a procedure that is not used in the United States. Reagents appeared to be in sufficient supply in the laboratory.

Bacteriological samples were sent out for analyses. Laboratory staff said that the samples were always negative. However, no paper work documenting these analyses was made available.

3.10 Recommended Facility Improvements to Nukus WTP

Most of the facilities at the plant are in acceptable states of repair and no physical improvements for them are deemed necessary at this time. These include the influent pump station, primary clarifiers, secondary clarifiers, filters, chemical feed equipment (except chlorination system), and transfer pump station.

Two of the facilities in need of upgrading are the chlorination system and the laboratory. The chlorine storage, supply, and feed systems should be totally replaced. This would include installing new scales, evaporators (two per plant), chlorinators (two 2,000 lb/day modules and two 1,000 lb/day modules), injectors, piping and valves. Also needed are venting systems for the chlorine room, alarm systems, and safety equipment. Table 3-1 summarizes recommended improvements to the chlorine system including a conceptual level cost estimate.

Table 3-1
Recommended Chlorination System Improvements at Each Plant

Equipment	Number	Unit Cost	Total Cost
Scales	1	$5,000	$5,000
Evaporators	2	10,000	20,000
Chlorinators			
2,000 lb/day unit	2	6,000	12,000
1,000 lb/day unit	2	5,000	10,000
Injectors	2	1,000	2,000
Piping & Valves		10,000	10,000
Venting Equipment		3,000	3,000
Alarms & Controls		4,000	4,000
Electrical		10,000	10,000
Safety Equipment		4,000	4,000
Subtotal FOB U.S.			$80,000
Shipping (Surface)			$50,000
Total			$130,000

Laboratory improvements recommended include new equipment and reagents as summarized in Table 3-2 (page 3-9). All this equipment is intended to improve control of the basic plant operations through monitoring of pH, turbidity, coliforms, chlorine residual, nitrates, and alkalinity. The list includes both counter top and portable models to provide flexibility in control and monitoring. More advanced laboratory equipment such as gas chromatographs are not recommended at this time. Ultimately, such equipment would be desirable. However, this advanced equipment should be provided in the future based on documented contamination being present in the raw water. Estimated costs include sufficient reagent volumes for 2 years of testing.

3.11 Urgench WTP

The Urgench WTP s identical in design and capacity to the Nukus WTP. It is located 90 km (56 miles) upstream of Urgench as shown in Figure 1. It is approximately 1.5 km across the river from the Nukus WTP. The Urgench WTP is located on the west side of the river whereas the Nukus plant is located on the east side. A process diagram of the plant is shown in Figure 2. Design criteria is summarized in Appendix B. The plant pumps finished water to the city of Urgench through a buried pipeline that is 1,000 mm in diameter.

- Pretreatment: Similar to Nukus but with no separate intake pump from the river. Influent pump station pumps direct from the river downstream from the dam to the plant's junction box.

- Primary Clarification: The same as described for Nukus WTP.

- Secondary Clarification: The same as described for Nukus WTP.

- Filtration: The same as described for Nukus WTP except that filters are operated automatically rather than manually.

- Clearwells: The same as described for Nukus WTP.

- Distribution Pump Station: Similar to Nukus WTP except that station is equipped with eight pumps instead of six. Firm capacity with one pump out of service is therefore greater.

- Chemical Feed Systems: The same as described for Nukus WTP.

- Chlorine System: The same as described for Nukus WTP. As at Nukus, only four of the eight chlorinators are functional.

- Laboratory: Similar to the Nukus WTP laboratory except better organized and maintained.

- Recommended Improvements to Urgench WTP: The same as for Nukus WTP; reference Tables 3-1 and 3-2 for chlorination and laboratory improvements.

Table 3-2
Recommended Laboratory Equipment at Each Plant

Equipment	Analysis	No.N	Unit Cost	Total Cost
Laboratory pH meter (Hach Model 44701 or equal)	pH, temp	1	$1,500	$1,500
Laboratory turbidimeter (Hach Model 2100N or equal)	turbidity	1	1,500	1,500
Laboratory spectrophotometer (Hach DR/2000 or equal)	Chlorine,	1	1,800	1,800
Portable pH,mv/temp meter (Baxter Model 250A)	pH, temp	2	1000	2,000
Portable Turbidimeter (Hach Model 2100P)	turbidity	2	1,000	2,000
Portable Coliform Laboratory (Hach 25697 MEL MF)	Coliforms	1	3,200	3,200
Pocket Colorimeter (Hach 46700-00)	Chlorine	1	300	300
Burets & Classware	Alkalinity	1	200	200
Reagents (2-year supply)			2,500	2,500
Subtotal Equipment FOB U.S.				$15,000
Shipping (Surface)				5,000
Total				$20,000

Section 4
Operations and Maintenance

4.1 Overview

Both WTPs are of the same design and capacity and were constructed in 1985. However, the Urgench plant is in a significantly better state of repair than the Nukus plant. Most, if not all, of the automatic control systems, e.g., filter backwash, etc., are functioning at the Urgench plant. At Nukus, essentially none of the automatic systems are functioning. The Nukus plant is being operated almost entirely in a manual mode.

Observations on operation and maintenance (O&M) of the plants' major unit processes are summarized below. Due to the short time (4 hours) spent at the Urgench WTP, these observations are not as thorough as they are for the Nukus WTP. However, because of the common standards for both plants, the observations are believed to typify both plants.

4.2 Primary Clarifiers

The primary (radial) clarifiers are being operated at a low target for solids (turbidity) removal. The target removal at the Nukus WTP is approximately 30 to 40%. Target removal at the Urgench WTP is assumed to be similar. The target removal rate should be increased at Nukus and probably at Urgench to approximately 60 to 70%.

This 60 to 70% removal rate will allow most of the solids and contaminants to be removed at the begining of the facility thereby improving performance of the subsequent processes, i.e., horizontal clarifiers, filters, and disinfection. The removal rate will also provide "reaction time" if raw water quality unexpectedly changes or an upset occurs to the chemical feed system.

The low-target solids removal rate was figured based on the low achievement standards – i.e., the GOST standards – and, in Nukus, on the difficulty in securing alum. When the raw water turbidity at the Nukus WTP drops to a level of 2.0 to 3.0 mg/L (26 to 39 NTU), alum feed is shut off. This is done because the plant can meet the turbidity standard of 1.5 mg/L by running the water through the clarifiers and filters without coagulant aids. This type of operation, while meeting the GOST standard, does not ensure proper removal of bacteria, protozoa and viruses, which are removed more effectively with coagulant addition.

The city of Nukus apparently does not have the finances to pay for the alum. The Ministry of Construction Materials is providing cut marble slabs to be used to barter for alum. The Nukus WTP also does not have adequate facilities to maintain sufficient storage of alum on site. Presently the city is building a storage building near the plant (to be completed this year) which will improve their ability to store chemicals. The existing conditions make reliable coagulant addition almost impossible at Nukus.

The situation at the Urgench WTP is slightly better for two reasons. There is apparently the financial means to purchase sufficient alum and there is also have adequate on-site storage. The operators stated that they had no problems obtaining alum; they only complained about the price of it.

4.3 Secondary Clarifiers

Both plants seemed to be properly operating the secondary (horizontal) clarifiers with target removal rates in the range of 50 to 60%. No specific improvements noted.

4.4 Filters

The first step to improve filter performance is to improve the operating efficiency of the primary clarifiers discussed above. With the combination of a target removal rate in the primary clarifiers of 60 to 70%, and a target removal rate in the secondary clarifiers of 50 to 60%, the filters will operate more efficiently and produce a lower turbid water. The lower turbid water will also allow the filters to run longer while producing a better quality of water as their length of run increases. The increased filter run-time will reduce the number of filter start- up cycles that occur. This will also reduce the possibility of passing contaminants during the filter's start up period.

Presently, the filters are loaded after completion of backwash without consideration to the water level on top of the filter. The water level could be located anywhere from just below the sand media to 2 meters above the sand media. This practice promotes air entrainment in the media, a condition that results in short circuiting and allows contaminates to pass right through the filters.

The water level on top of the filter should be maintained at a predetermined starting level after backwash. The operating level will increase in time due to "loss of head." Filter backwashing should occur at a predetermined "loss of head" water level (not maximum level) based on particle breakthrough considerations.

The filters need to be operated at their hydraulic design loading rate. Operating a filter at or near its design loading rate will provide the maximum efficiency for the filter during its complete operation.

At the time of the field visit to the Nukus WTP, six of the 18 filters were out of service needing some type of maintenance (primarily sand replacement). The apparent design loading rate for each filter is 12,500 m^3/day based on meeting plant capacity of 200,000 m^3/day with 16 filters operating. With six filters out of service, the 12 on-line filters are being loaded at 16,700 m^3/day, which is 33% greater than their design loading rate.

In that the filters have no design features for backwash aided devices, considerations should be given to provide such devices, e.g., surface washers, air scrubbers, etc.

4.5 Chlorination Systems

The plants are designed to enable chlorine to be added at two locations; first, at the influent to the secondary clarifiers and, second, at the finished water clearwells. This is a good design feature. However, chlorine addition is often omitted or minimized with minimal disinfection benefits resulting from this otherwise well-designed system.

Normal operation is to monitor residual chlorine at the two locations. Residual chlorine monitored at the secondary clarifier is 0.08 mg/L and 0.10 mg/L in the finished water. While the staff was able to detect residual chlorine value using methyl orange titration in their lab, tests performed by Mr. Gierer with potable test equipment indicated very little or no chlorine residual. In light of the highly turbid water both in the secondary clarifiers and in the clearwells, this low level of chlorine residual is academic because such a low level is basically useless for disinfection. "Breakpoint" chlorination is necessary for adequate disinfection.

Standard operation regarding chlorination is "not to be too concerned about it" in that it is understood that the water is rechlorinated in the distribution system by "others," presumably by the two cities. During the site visit the chlorine system at Nukus was routinely shut down and it was noticed that during the 4-hour visit to the Urgench plant, that plant's chlorination system was also shut off. During this time both plants were operating at their design capacities of 200,000 m^3/day.

Chlorine feed rate is basically unregulated. When a new (800 kg) tank is put into use the feed rate is high due to high pressure in the tank. After the tank has been in service and starting to empty, the pressure is low and less chlorine is fed. Although the Nukus WTP is equipped with eight chlorinators, at the time of the inspection only four were operational. None of the four operational chlorinators had flow indicating balls in the rotameter tubes. This again reflects the basis of operation, which is just to let the tank empty at its own pace.

The chlorination systems at both plants should be replaced as discussed above. Once the systems have been replaced, dosages should be maintained that would ensure that "breakpoint" chlorination is being achieved. The new system should be based on chlorine dosages and contact times sufficient to destroy harmful organisms. The transmission pipeline could be used for this purpose as it is understood that only repumping occurs along its route for considerable distance. However, an evaluation needs to be made of the transmission pipeline to confirm this assumption.

4.6 Laboratories

Laboratory equipment used at both plants is old but useable. However, there is concern regarding repeatability and reliability of the results and it would be desirable to provide new laboratory equipment at each plant for this purpose. The equipment listed in Table 3-2 is recommended.

Section 5
Recommendations

The following recommendations have been developed based on conclusions from the field investigation:

(1) **The GOU should adopt the WHO guidelines for potable water.** These guidelines should be carried out in a phased approach with Phase I improvements based on (a) **eliminating contaminants such as bacteria and protozoa** that cause acute health problems and (b) **conducting engineering and risk assessment studies** as described below leading to overall improvements to the regional water systems. Phase II improvements would be based on conclusions from the studies and could include design/construction projects related to advanced treatment systems or to other system-wide water system improvements.

(2) Specific Phase I improvements relating to reduction of contaminants causing acute health problems should be based on **reducing turbidity to 1.0 NTU and increasing disinfection to provide a "free" chlorine residual of 0.2 mg/L in the finished water.** To make these improvements at the WTPs, it will be necessary to carry out the following tasks:

(a) **Install new chlorination systems** at both plants. The components of the chlorination system would include scales, evaporators, chlorinators, injectors, and associated piping and valves. Venting systems for the evaporator/chlorinator room(s), alarm systems and safety equipment would be included. Two evaporators and four chlorinators (two 2,000 lb/day modules and two 1,000 lb/day modules) per plant would be provided. Estimated costs are $170,000 per plant including surface shipping.

(b) **Provide new laboratory equipment** as described in this report that will ensure that plant processes are operating properly and efficiently. An adequate supply of reagents is also needed. Estimated equipment and reagent costs are $20,000 per plant, including shipping costs.

(c) **Provide operator training** to optimize O&M of the clarifiers, filters and other unit processes in order to meet the proposed new standards. Operator training is also needed in O&M of the new chlorinators and laboratory equipment. Part of this training may involve site visits to U.S. water plants by selected Uzbek operators.

(**Note:** It is anticipated that the training would be provided by the NIS Exchanges and Training (NET) Project, developed by the Academy for Educational Development (AED), as part of the WTP operator course scheduled for early 1995.)

(3) **The GOU should institute an annual budget** to ensure adequate operation and

maintenance of the plants including a reliable supply of chemicals and repair parts. Additional Phase I studies that should be undertaken include a risk assessment study of the raw water and a study of the distribution systems. Scope of Work for these studies should be developed with concurrence with the GOU. Proposed scopes of work are as follows.

(4) **Conduct a risk assessment/advanced treatment feasibility study** to determine if exposure levels from contaminants, such as pesticides and metals, in the raw (river) water are great enough to justify adding advanced treatment processes at the plants. Specific study tasks would include the following:

(a) Review available raw (river) water quality data. If sufficient data is available, a risk assessment would be made based on this data. If the data indicates that concentrations of parameters are sufficiently low enough to suggest a low level of health risk from water consumption, no further assessments will be made and advanced treatment processes would not be recommended.

(b) If existing (or sufficient) data on background raw water quality is not available, a 12-month sampling effort would be needed to establish concentrations from which to base exposure levels. A preliminary assessment could be made based on 6 months of sampling with a final report based on 12 months of sampling. If this data suggests only low levels of contaminants in the raw water, thus minimum exposure levels, the conclusion would again be to not install advanced treatment processes.

(c) If the data indicates high enough concentrations of pesticides and other contaminants in the raw water to constitute a health risk, the assessment would be expanded to evaluate the health risks from other exposure pathways based on human behavior patterns in the area. Such pathways could include washing and sanitary practices, oral ingestion, inhalation and/or dermal contact from agricultural spraying of pesticides. Final determination on the need to provide advanced treatment for the potable water systems would be based on conclusions of the area wide risk assessment.

(d) After the conclusion has been reached that advanced treatment is needed, an engineering study would be made of the various alternatives to provide this treatment. Such alternatives could include activated carbon with regeneration at the plants, nanofiltration at the plants, smaller nanofiltration plants located in each of the cities of Nukus and Urgench sized for consumptive capacity only, and other such alternatives as may be deemed feasible. The recommended alternative would be the alternative that is most cost effective and implementable.

(5) **Conduct an engineering study of the distribution systems** of Nukus and Urgench to include (a) the distribution systems of both plants to determine how finished water from the plants is managed both in the transmission pipelines and in the cities

and (b) the volumes of water being utilized for consumptive purposes. Specific study tasks would evaluate the following:

(a) The number of booster pump stations along the transmission mains would be studied and a description of the facilities at each pump station, i.e., pumps, chlorinators, controls, etc., would be completed. Evaluation would be based on available engineering drawings of the stations and on operator interviews. Recommendations would be made for any needed improvements to the pump stations.

(b) The location, size, and materials of construction of the transmission pipelines. A general assessment would be made of the state of repair of the transmission pipelines based on any "C" factor determinations that could be made from available pressure readings at pump stations along the pipelines and from documentation of any known leaks or problem maintenance segments as determined from operator interviews. Recommendations would be made for pipeline improvements needed.

(c) A general assessment would be made of the state of repair of the distribution systems within the cities of Nukus and Urgench. The assessment would be based on review of any maps or records available and from interviews with system operators. The assessment would include documentation of known leaks and an estimate of the amount of water leakage within the distribution systems based on records and interviews.

(d) The chlorine residuals would be evaluated within the transmission pipelines and within the city distribution systems. This evaluation would be made by reviewing any available records and by taking representative water samples throughout the systems.

(e) The study would also attempt to estimate the volume of water used for consumption within the two cities and compare this with the amount of water being pumped by the treatment plants. This estimate would be based on the probable number of people being serviced by the plants and on the per capita consumption of water based on observed practices. Industrial and commercial uses of water, if any, would be estimated. This information would be useful in helping evaluate the capacity of advanced treatment alternatives that could be located within the cities themselves – rather than at the plants, should advanced treatment be needed.

Appendix A
Comparison of Water Quality Parameters

Table A-1
Comparison of Water Quality Parameters (Representative List)
(R

Parameter[1]	Uzbek[2]	USEPA[3]	WHO[4]
Microorganisms			
Bacteria	100/m3	<1	0
Giardia	3/L	0	0
Turbidity, NTU	20	<0.5	<1
TDS	7.0[5]	500	1,000
Inorganics			
Aluminum (Al)	0.50	0.20	0.20
Magnesium (Mg)	0.25	0.05	-
Arsenic (As)	0.05	0.05	0.01
Lead (Pb)	0.03	0.0	0.01
Manganese (Mn)	0.1	0.05	0.5
Copper (Cu)	1.0	1.3	2.0
Zinc (Zn)	5.0	5.0	3.0
Nitrates (NO_3)	45	45	45
Sulfates (SO_4)	500	250	-
Chlorides	350	250	250
Fluoride	0.7	4	1.5

[1]mg/L unless otherwise noted
[2]GOST Standards
[3]1994 Standards
[4]1993 Guidelines
[5]Equivalent mg/L

Appendix B

Design Criteria: Nukus and Urgench Water Treatment Plants

Pretreatment

Raw Water Pump Station(s)
  Number of Pumps – four each
  Pump Capacity, each – 120,000 m^3/day
  Operating Pressure – 3.0 atmospheres

Coarse Bar (trash) racks – four ahead of the station, another four in canal for Nukus WTP

Traveling Screens – four, one in each of the wet wells leading to the influent pumps

Primary Clarification

Type Clarifier – Circular (radial)

Number – four each (two per train)

Capacity, each – 60,000 m^3/day

Diameter – 50 meters

Hydraulic Loading Rate – 30.6 m^3/m^2/day (0.5 gpm/sf)

Volume – 7,500 m^3

Secondary Clarification

Type Clarifier – Rectangular (horizontal)

Number – 18 each (nine per train)

Capacity, each – 12,500 m^3/day

Dimensions – 6 m wide, 90 m long (20 m floc and 70 m settling chambers), 4.5 m deep

Filtration

Number – 18 @ 12,500 m^3/day each. Total capacity of 200,000 m^3/day based on two filters out of service (one per train).

Dimensions – 6 m wide, 9 m long, 2 m of media

Hydraulic Loading Rate – 0.16 m3/min per m^2

Backwash Rate – 30 m^3/min (without backwash aid system)

Clearwells

Number – three each

Capacity, each – 300,00 m^3/day

Water Depth – 6.5 m

Process Pumps

Sludge Pumps – 3 @ 800 m^3/day each

Backwash Pumps – 2 @ 3,200 m^3/hr each

Service Water Pumps – 3 @ 200 m^3/hr each

Backwash/Service Water Reservoirs

Number – 2 each

Capacity, each – 100,000 m^3

Chlorine Feed System

Chlorinators
Number – eight total, five dedicated for primary disinfection and three for final disinfection
Feed Rate – 12 kg/hr (624 lbs/day) each

Storage facilities – One 800 kg and two 50 kg tanks

Chemical Feed Systems

Alum Storage/Mixing Tank – six @ 97 m^3 each [will hold 4 to 5 tons of dry (rock) alum]

Alum Solution (liquid) Storage Tank – three @ 600 m^3 each

Alum Solution Feed Tank – two @ 48 m^3 each

Alum Feed Pumps – three @ 8.5 m^3/hr each

Polymer Solution Feed Tank – two @ 24 m^3 each

Polyacrylamide Feed Pumps – two @ 8.5 m^3/hr

Distribution Pump Stations

Nukus

Number of Pumps – six each

Capacity, each – 85,000 m^3/day

Operating Pressure – 30 atmospheres

Firm Pumping Capacity – 425,000 m^3/day (112 mgd) w/one pump out of service

Urgench

Number of Pumps – eight each

Capacity, each – 85,000 m^3/day

Operating Pressure – 30 atmospheres

Firm Pumping Capacity 595,000 m^3/day (157 mgd) w/one pump out of service

Distribution Pipelines

Nukus – 280 km (174 miles) of 1,200 mm diameter ductile iron pipe

Urgench – 90 km (56 miles) of 1,000 mm diameter ductile iron pipe